MIDA 1

Prediction

1. Introduction

- Prediction problem, prediction error
- Transfer function, zeros and poles
- Random Variable v: $\mathbb{E}[v]$, $Var(v)$
- Random Vector $\underline{v}$: $\mathbb{E}[\underline{v}]$, $Var(\underline{v})$, ρ
- Random/Stochastic Process $v(t)$: $\mathbb{E}[v(t,s)]$, $Var(v(t))$, $\gamma(t_1, t_2)$
- Stationary Process
- White Noise (i.e. Unpredictable Signal)

2. MA, AR and ARMA Processes

- MA(n): Moving Average Process
  → $\mathbb{E}[v(t)]$, $Var(v(t))$, $\gamma(\tau)$
  → Dynamic representation
  → MA(n) vs. White Noise
  → MA(∞)
- AR(n): Autoregressive Process
  → AR(1) as MA(∞)
  → AR(n) vs. MA(n)
  → $\gamma(\tau)$: Yule-Walker equations
- ARMA(n_a, n_c)

3. Frequency Domain

- Spectral representation:
  real spectrum $\Gamma(\omega)$, complex spectrum $\phi(z)$
- Anti-transform formula
- Fundamental theorem of spectral analysis
  (magic formula in real and complex form)
- ARMA process: dynamical representation
  (long division and interpretation of coefficients w_i)
- ARMA process: multiplicity of representations
- Canonical representation

4. Prediction

- Fake problem (knowing the past of η)
- Real problem (knowing the past of v)
- Prediction for MA(1), AR(1), ARMA(n_a, n_c)
- Exogenous variables: ARX, ARMAX

Identification

5. PEM (Prediction Error Minimization) methods

- LS (Least Squares) identification method
- Identifiability: invertibility of $S(N)$ and $R(N)$
- Persisten excitation
- Uniqueness of estimation
- ML (Maximum Likelihood) method
- Asymptotic analysis of PEM methods:
  performance of identification models
- Asymptotic behaviour of PEM
- LS estimate procedure

6. Model Complexity Selection

- Naive approach
- FPE (Final Prediction Error)
- AIC (Akaike Information Criteria)
- AIC vs. FPE
- MDL (Minimum Description Length)

7. Durbin Levinson Algorithm

- Recursion from AR(n) to AR(n+1)

8. Time Series Analysis

9. Recursive identification methods

MIDA 2

Chapter 1

Non-parametric (direct/constructive) black box identification of I/O systems using state-space models.

- Representations:
  1. State space
  2. Transfer function (I/O)
  3. Convolution of input and input resposne (IR)
- Change of representation (*)
- Observability, controllability of a dynamical system
- (*) 4SID method (without/with noisy meas. of IR)

Chapter 2

Parametric identification of black box I/O systems with a frequency domain approach.

- Parametric system identification:
  Step 1: Frequency domain dataset
  Step 2: Model class selection $M(\theta)$
  Step 3: Performance index $J(\theta)$
  Step 4: Optimization $\hat{\theta}$

Chapter 3

Kalman filter for software sensing using feedback on white box models.

- Motivations and goals of Kalman filter theory
- Software sensing
- Basic system
- KF for the basic solution of the basic system
- Block scheme representation of KF
- Extensions of basic problem of basic systems:
  1. Exogenous input
  2. Multi-step prediction
  3. Filter 11
  4. Time-varying system
  5. Non-linear systems (*)
- Asymptotic solution of KF:
  1^{st} and 2^{nd} asymptotic theorems
- (*) Extension of KF to non-linear systems

Chapter 4

Black box methods for softw. sensing without feedback.

- Black box estimate of $\hat{x}(t)$ from $y(t)$, $u(t)$
- Black box software sensing vs. KF software sensing
- Architectures: 4 types of

Chapter 5

Gray-box system identification $^{(1)}$ using Kalman filter, $^{(2)}$ using simulation error methos (SEM).

- Gray-box system identification using KF
- Parametric system identification based on SEM
- SEM in black box methods:
  PEM (prediction error methods) vs. SEM

Chapter 6

Minimum variance control (MVC). Design of optimal feedback controllers using the theoretical background of the MIDA 1 course.

- Setup of the problem
- Simplified problem 1: noise free
- Simplified problem 2: with noise
- General solution
- Stability and performance analysis

Appendix

- Discretization of an analog system